THE EFFECT OF CONTINUOUS NOISE ON SHORT TERM MEMORY PERFORMANCE TASKS

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Monterey, California

THESIS

THE EFFECT OF CONTINUOUS NOISE
ON
SHORT TERM MEMORY PERFORMANCE TASKS

by

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Analysis of the data collected indicated that continuous noise at a sound level pressure of 85 dB (re .0002 dyne/cm^2) had no effect on the subjects short term memory. Levels of difficulty resulted in a significant difference in performance on the serial short term memory task used in this experiment.

The Effect of Continuous Noise

on

Short Term Memory Performance Tasks

by

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Lieutenant, United States Navy
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I. INTRODUCTION

Throughout the past 20 years researchers in the fields of Psychology, Human Factors Engineering and other related fields have expended a significant effort in the area of noise and its effect on human performance. While noise has long been considered an undesirable contaminant of man's environment (Committee on Environmental Quality, 1968) it is not clear from research studies the manner in which noise typically effects task performance.

Guignard (1965) concluded that in tasks calling for both speed and skill, noise increases the incidence of mistakes. Broadbent (1954) concluded that noise adversely affects performance on signal detection, choice reaction and complex sensorimotor tasks. Additionally Broadbent (1953) demonstrated that in serial reaction tasks (where a new stimulus appears as soon as a satisfactory response has been made) noise had an effect, not in the average work rate but in the form of mistakes. It has also been shown that time-judgement may be altered by noise, Jerison (1959). Broadbent and Gregory (1965) found deterioration in vegilance under noisy conditions when signals were frequent but not when they were infrequent. Roth (1968) stated that:

> "In general, it may be said that the effect of intense noise on work is distracting rather than disabling and noise is most troublesome when it is irrelevant to the task in hand."

On the other hand, Park and Payne (1963) and Samuel (1964) concluded that once the transient effect (the onset of noise or the sudden removal of noise) has passed, many tasks are performed as efficiently in loud noise as in quiet conditions. Additionally, the results of studies by McBain (1961), Watkins (1964) and Davies and Hocket (1966) involving continuous tasks have demonstrated improved performance under noise. Also, Rivenes (1975) demonstrated that noise has no effect on performance of cognetative tasks.

The relationship between noise and human performance is addressed in the present paper. The present study is motivated by the apparent lack of agreement among the results of researchers in the area, by the presence of noise in the authors environment and by the authors belief that short term memory (STM) plays an essential part in complex human performance.

Fitts and Posner (1967) defined STM as:

> "A system which loses information rapidly in the absence of sustained attention."

Short term memory provides man with a means for storage, at least temporary, of events of the recent past. It is this necessary capacity which allows him to determine the immediate context of those events.

Man functions, particularly in the present author's environment, principally as the decision maker. Although it is his capability to select the correct course of action from those stored in long term memory, it is short term memory which provides the ability to review a chain of recent stimuli. Reviewing the chain of recent events enables the operator to decide if action is necessary, and if so what type.

As a Naval Officer, the author is exposed to many varied noise backgrounds, from the relatively high intensity noise levels of machinery spaces and adjacent spaces to the relative quiet of the bridge on the mid-watch. In each of these different noise environments, man is required to perform a wide variety of increasingly complex cognetive tasks. On sophisticated weapons platforms, such as Navy ships and aircraft, operators of complex systems receive stimulation from a wide variety of sources. A given chain of events dictates one response, a different chain another different response. Examples of shipboard tasks involving STM are: a) "on the spot" diagnosis of equipment malfunctions; b) predicting tracks and future position from

Primary Position Indicator displays; c) controlling engineering plants in remote manual mode during casualities; and d) steering the ship, where the helmsman uses feedback from the compass and the rudder position indicator to guide his actions. In most of these environments, the noise level is of moderate intensity, (80-90 dB re .0002 dyne/cm^2).

The hypothesis tested in this study is that continuous noise of moderate intensity does not have an effect on human performance of STM tasks.

II. METHOD

A. SUBJECTS

The subjects for the experiment were 20 male Naval line (aviation and surface) officers, of age 26 to 32 years, from the student population at the Naval Postgraduate School. U. S. Navy physical requirement for the S's preclude other than normal visual and auditory acquity, and color blindness. Subjects were volunteers and performed without monitary compensation. Subjects were not told the purpose of the experiment nor the exact time required for them to perform the task.

B. APPARATUS

1. Response Analysis Tester (RATER)

The experimental device used to measure the subjects performance under the different conditions was the Response Analysis Tester (RATER), Model 3. The RATER is manufactured by General Dynamics Convair Division and is a psychomotor testing instrument designed to provide reliable measurement of impairment of response speed/accuracy and short term memory for colored or geometrical patterned stimuli. The basic task required the subject to press the correct response button for each of four colors. The colors were

automatically displayed in a random sequence. A card with four colored corners, corresponding to the colors displayed by the RATER display unit, was placed under the response buttons and remained there for the entire experiment, (See Figure 1). Total responses and correct responses were automatically displayed on counters installed in the RATER control unit. (See Figure 2)

The visual stimulus colors presented by the RATER were Red, Blue, Yellow and Green.

2. Noise Generation

Continuous white noise at 85 dB was generated by a Lafayette Instrument Company #1431 white noise generator and delivered to subjects via headphones.

3. General Layout

Subjects were seated at a desk in an i.a.c. Inc. controlled acoustical environment booth (with an ambient noise level of 30 dB). Upon the desk in front of the subject, was the RATER display unit and an intercom unit, (See Figure 3). Located outside the booth were the RATER control unit and the white noise generator. (See Figure 4)

C. PROCEDURE

Subjects were seated at the desk in the i.a.c. booth and shown the display unit. After they were shown the proper placement of the fingers (using the thumb and index

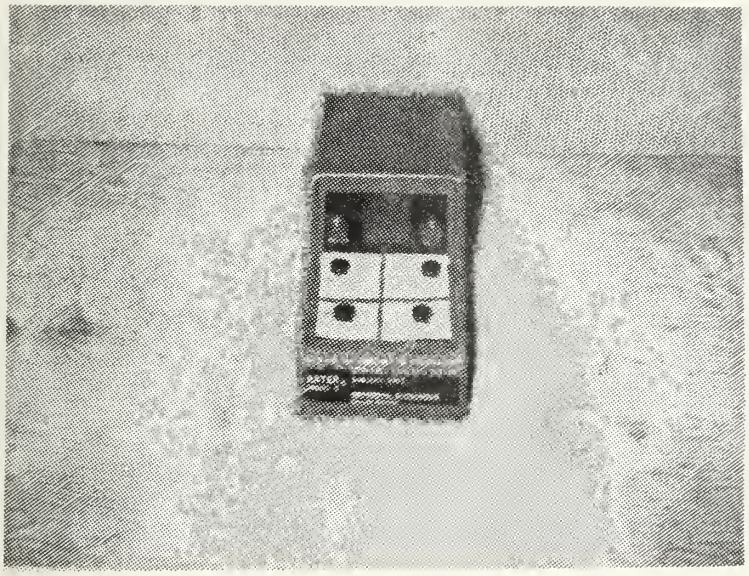

FIGURE 1: THE RATER DISPLAY UNIT

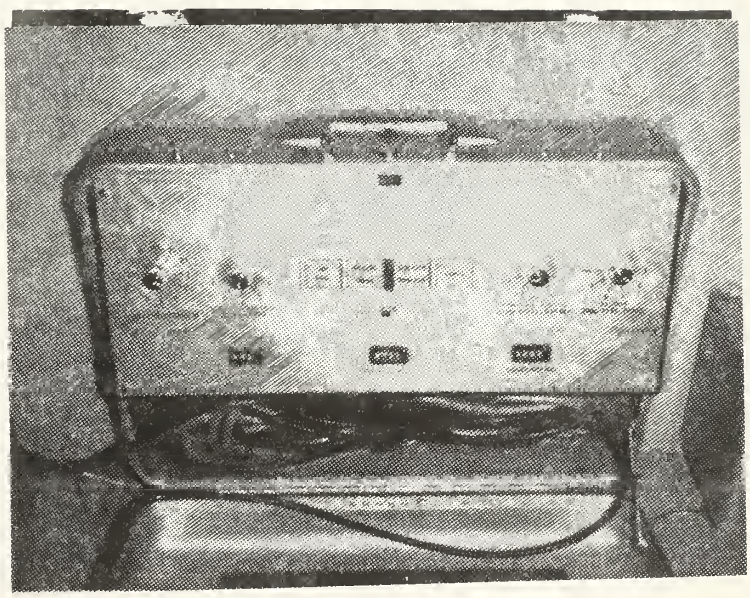

FIGURE 2: THE RATER CONTROL UNIT

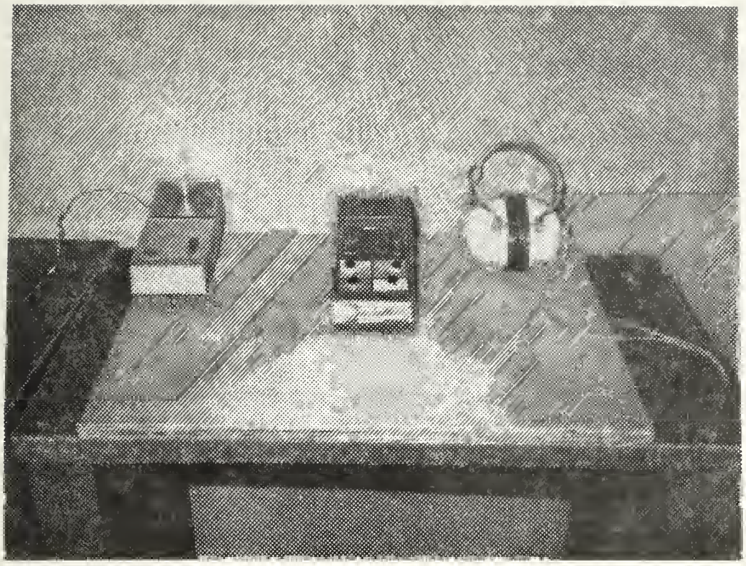

FIGURE 3: GENERAL LAYOUT INSIDE BOOTH

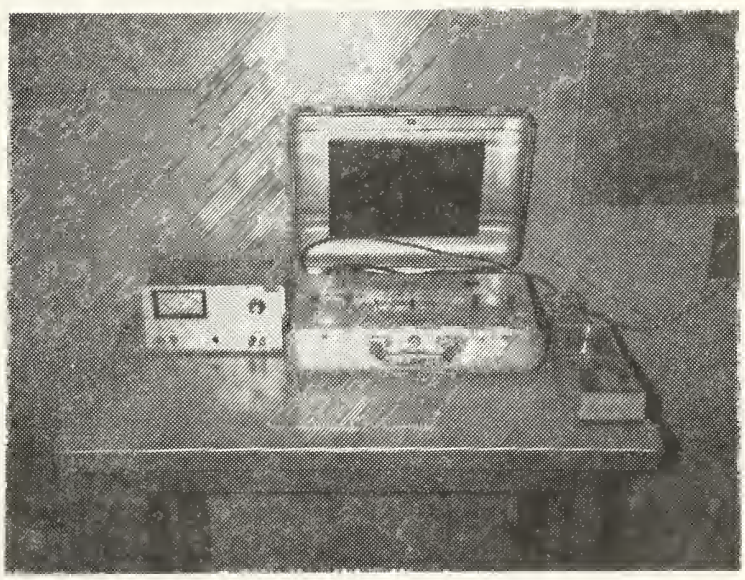

FIGURE 4: GENERAL LAYOUT OUTSIDE BOOTH

fingers of each hand for conformity) the booth door was closed and all further instructions communicated via the two-way intercom.

The task instructions (Appendix A) were read to the subjects and they were given the opportunity to ask questions related to performance of the task. When the subjects indicated they understood the task they received two, 2 minute practice runs in either delay 2 or delay 3 depending upon which group they were in. After completion of the practice runs, subjects were read the additional instructions (Appendix A) and those who were members of the experimental group were instructed to put on the earphones.

The experiment consisted of 5 repeated runs at the task in either delay 2 or delay 3 mode, depending on their group. Each run lasted 2 minutes. Successive runs were separated by the 5-8 seconds required to re-zero the counters and adjust the presentation rate on the RATER control unit. Each of the 5 test runs started with a different presentation rate of the initial 2 or 3 colors depending on the delay mode in use. If, for example, a subject in the delay 3 group would see the first three colors for 2 seconds each on the first run, 1.5 seconds each for the second run, 1.0 seconds for the third run, 0.75 for the fourth and 0.5 seconds for the fifth and final run. Practice runs utilized the 2.0 seconds per color for the initial colors.

fingers of each hand for conformity) the booth door was closed and all further instructions communicated via the two-way intercom.

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Once the initial 2 or 3 colors were displayed, further colors were presented only when the proper response buttons were depressed. The task was self paced after the initial 2 (or 3) colors were presented.

Upon completion of the experiment subjects were thanked for their time and instructed not to discuss the task with other subjects. They were also encouraged to ask any questions concerning the purpose of the experiment, its design, or the equipment used for the experiment and these questions were answered at this time.

D. DESIGN

The experiment was designed to consider three factors. The principle factor of concern was noise and consisted of two levels. The quiet level was the ambient noise level (30 dB) in an i.a.c. Inc. sound-attenuating booth. The moderate noise level consisted of electronically induced 85 dB auditory stimulation via headphones. Two levels of task complexity were examined. The least complex level required the subjects to respond to a visual stimulus presented two presentations prior to the stimulus they were presently viewing (Delay 2 mode). The complex task required the S's to respond to the stimulus which preceeded the present stimulus by three (Delay 3 mode). The third factor consisted of five levels of stimulus set. Each of the five runs presented to the S's consisted of a different

rate (seconds per stimulus) of presentation of the initial two or three stimuli (depending on the delay mode group to which a particular subject was assigned) which the subject received. Twenty subjects were randomly divided into two groups, the control group and the experimental group. The control and experimental groups were each randomly subdivided (Figure 5) into two additional groupings, one assigned to the delay 2 mode and one to the delay 3 mode, such that there were five S's in the noise/delay 2 group, five S's in the noise/delay 3 group, five S's in the no noise/delay 2 group and five S's in the no noise/delay 3 group. All 20 subjects received the five different levels of induced set, 2, 1.5, 1.0, 0.75 and 0.5 seconds duration of initial stimulus presentation.

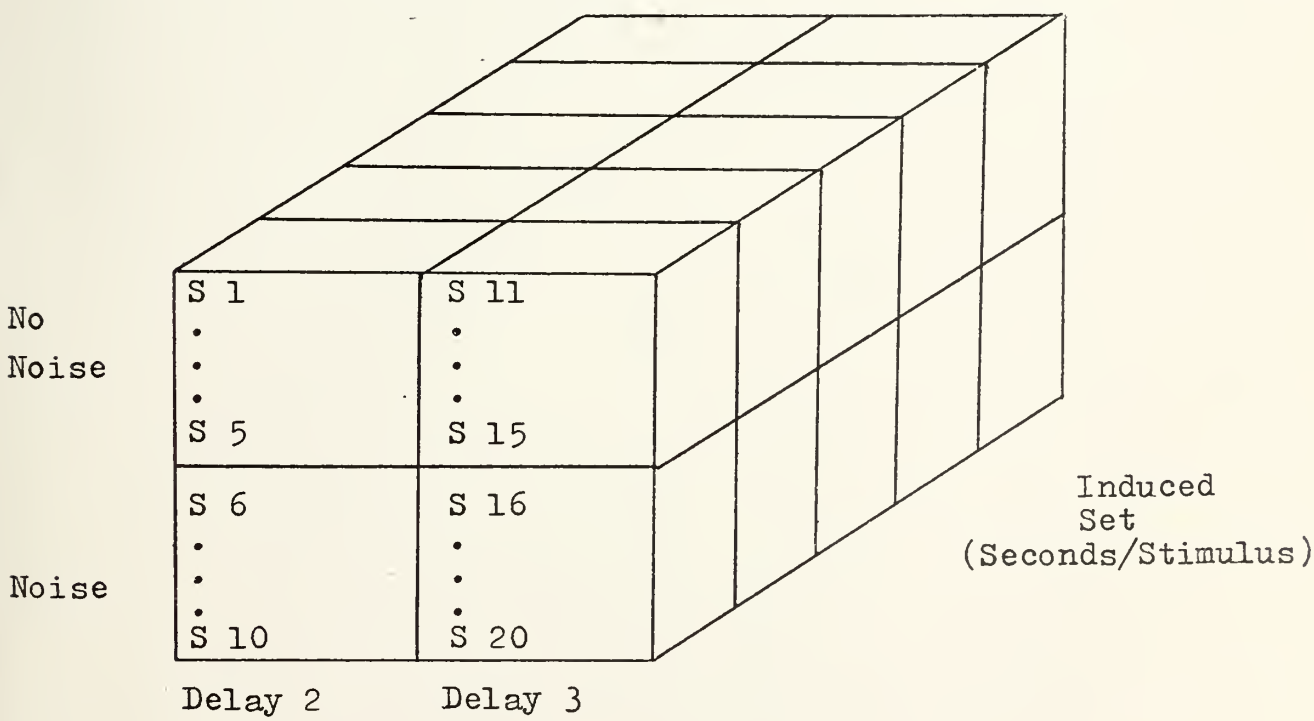

FIGURE 5: CONCEPTUAL MODEL OF THE EXPERIMENT

The dependent variable was the number of correct responses divided by the number of total responses, i.e., "percent correct". Percent correct was used since it was desired to have a measure of the subjects accuracy, not rate.

Data from the experiment was analyzed in accordance with a three-way factorial analysis of variance (ANOV), Bruning and Kintz (1968).

III. RESULTS

A three way ANOV (See Table I) was performed using the data from the experiment. The factors investigated were noise level, difficulty level and induced set. Difficulty level resulted in significantly different performance beyond the .05 level. Noise level and induced set resulted in no measurable difference in group performance. Raw data, in percent correct form is included in Table II.

SOURCE	d.f.	S.S.	M.S.	F	P
Between Subjects	19	11877.25	-	-	
Noise	1	00.25	00.25	0.00002	
Delay	1	2514.02	2514.02	4.49	.05
N x D	1	406.41	406.41	.726	
Error	16	8956.57	559.786		
Within Subjects	80	4353.50	-	-	
Initial Set	4	398.92	99.73	1.876	
I x N	4	85.41	21.35	0.402	
I x D	4	227.99	56.997	1.07	
I x D x N	4	239.06	59.76	1.12	
Error	64	3402.12	53.158	-	
Total	99	16230.75			

TABLE I: THREE FACTOR ANOV SUMMARY TABLE

Subjects

Initial Set

	2.0	1.5	1.0	0.75	0.50
S 1	64.8	59.8	72.5	62.1	77.6
S 2	79.1	71.1	66.9	62.0	70.7
S 3	77.3	78.4	72.0	70.0	78.3
S 4	76.1	68.2	68.9	67.5	69.4
S 5	53.2	61.0	62.6	51.5	55.7
S 6	56.8	59.2	55.8	54.0	52.7
S 7	73.4	75.7	75.8	61.3	72.9
S 8	85.0	76.0	72.9	80.2	89.4
S 9	61.5	49.3	54.8	59.3	69.0
S 10	51.1	51.9	52.0	56.1	52.3
S 11	52.0	80.0	52.1	54.5	100.0
S 12	53.9	66.1	55.5	52.6	50.5
S 13	44.6	47.8	42.6	41.5	40.5
S 14	50.5	51.5	51.4	54.3	46.6
S 15	48.8	45.5	56.1	54.3	52.0
S 16	48.1	59.1	44.9	41.9	49.1
S 17	45.4	56.0	57.1	46.2	46.9
S 18	93.5	89.2	84.8	67.8	70.3
S 19	50.6	53.8	53.4	43.4	57.3
S 20	59.2	55.7	60.4	64.1	50.3

TABLE II: RAW DATA (Percent Correct Responses)

IV. DISCUSSION

The results indicate no significant difference in performance of the short term memory task due to continuous noise. This result was consistent for both delay conditions. The results indicated that subjects performance at the most difficult task, delay 3, was significantly less accurate (55.85 average percent correct vs 65.89 average percent correct) than their performance at the delay 2 task. The third factor, initial stimulus set, had no effect, nor did any of the two way or three way interaction terms.

The results of the analysis of variance tends to support the hypothesis that moderately loud, continuous noise has no effect on human performance on tasks requiring short term memory.

The results of this experiment tend to support the filter theory of Broadbent (1958). The subjects in the noise group commented afterwards that the noise had no apparent effect on them. This is fully explained if their filter mechanism actually filters out the superfluous, in this case noise, stimulus and passes on the pertinent stimulus for cognetive processes. In order to successfully process the stimuli, each subject had to store two or three

stimuli for a period of time prior to making a response. Upon the correct response, a new stimulus would immediately appear. Thus one could conclude that the S's were required to be attentive to their task at all times and thus the noise would be filtered out. Two observations tend to weaken the above conclusion. At the completion of each 2 minute run, the S's received no stimulus other than noise or relative quiet, depending on their group. During this 5 to 8 second period, those subjects in the noise group could divert their attention to the noise. In all cases the S's committed no errors upon commencing the next run until the eight or ninth response. The subjects seemed equally adept at shifting their attention from the quiet or noisy background to the task at hand. The second observation is that in almost no case of an error did the S's make only one error prior to obtaining a correct response. Thus subjects, when they had committed an error, had no new stimuli to process until the correct response was recovered. During this period, albeit short, the subjects under noise had the opportunity to divert their attention from the visual task to the noise stimulus.

The analysis indicates that the presence of noise, to which the filter theory postulates the S's attention would be diverted, did not significantly effect their performance. Thus the filter theory does not explain fully the results.

The present author postulates that the continuous noise is not a stimulus to which the subject would turn his attention. The subjects in the noise group adapted the noise as part of the background just as those subjects in the no noise group would consider the relative quiet of the booth their background.

The experimental results indicate no significant change, increase or decrease, in the subjects performance over time as measured over the five different initial stimulus sets. In that the noise level was of moderate intensity (85 dB), arousal theory (c.f. Broadbent, 1971) could have explained any decriment in performance over time had such a decriment be observed. That is, initially the noise, since it was of moderate intensity, could have increased the attentiveness of the subjects, i.e., aroused them to a point which would have facilitated the performance of the serial short term memory task. With time the arousal effect of the continuous noise, of constant intensity, would have diminished and thus the subjects performance. As this was not the case, it seems logical to conclude that the subjects in the noise group rapidly adapted to their environment to such degree that it was perceived as background. Thus, it had no more effect on their performance than the relatively quiet background of the no noise group.

It is probable that the rapid adjustment to the noise background by the subjects of this experiment may be

attributed to the almost constant exposure to noise by the Naval officers in their normal environment. For this reason it is recommended that this experiment be repeated using subjects from the civilian population.

Continuous noise of moderate intensity is certainly a part of our noise environment but by no means the only part. It is recommended that further experiments, using the RATER, be conducted to examine the role of noise on human performance. Continuous noise of higher intensity (100 dB+) should be introduced as a factor. Intermittant noise both at a moderate level and the higher level should be examined for its effect on human performance. Tasks involving time sharing under the various conditions of noise described above could be examined to ascertain if noise is more than just a part of our environment to which we can adapt.

APPENDIX A

INSTRUCTIONS TO SUBJECTS

The following instructions were read to each subject.

A. INSTRUCTIONS TO SUBJECTS IN DELAY 2 GROUP, NO NOISE

A sequence of colors, e.g., red, green, green, yellow, blue and so on, will be presented on the small screen you see before you.

Your task is to press the proper response button, color coded to correspond to the presented colors, as follows; you are to respond to the color which preceded the color being presented on the screen by two. If for example the sequence is yellow, green, blue, red, and so on, you would observe the yellow, then the green, then a blue color on the screen. While the blue color is showing you would press the yellow button, that is the button over the yellow square. When you press the proper button, in this case the one in the yellow square, the next color in the sequence will be displayed, in this example red. You now press the button corresponding to the color which preceded the present color by two, that is the green button in this example. You are to proceed until the sequence is complete. Do you have any questions?

You are to proceed as fast and accurately as possible.

We will now commence the first practice run.

We will now commence the second practice run.

Now we will commence the test. You will get 5 runs, each separated by a few seconds. Are you ready?

B. INSTRUCTION TO SUBJECTS IN DELAY 2 AND NOISE GROUP

These instructions were exactly the same as in A above with the addition of the following instruction read to the subjects after the last paragraph in A above.

Please place the earphones on and let me know when you have them on. I will start the test then.

C. INSTRUCTIONS TO SUBJECTS IN DELAY 3 GROUP, NO NOISE

A sequence of colors, e.g., red, green, green, yellow, blue and so on, will be presented on the small screen you see before you.

Your task is to press the proper response button, color coded to correspond to the presented colors as follows; you are to respond to the color which preceded the color being presented on the screen by three. If, for example, the sequence is yellow, green, blue, red, blue and so on, you would observe the yellow, then the green, then the blue, then a red on the screen. While the red color is showing, you would press the yellow button, that is the button over the yellow square. When you press the proper button, in

this case the yellow button, the next color in the sequence will be displayed, in this example blue. You now press the button corresponding to the color which preceded the present color by three, that is the green button in this example. You are to proceed until the sequence is completed. Do you have any questions?

You are to proceed as fast and accurately as possible.

We will now commence the first practice run.

We will now commence the second practice run.

We will now commence the test. You will get 5 runs, each separated by a few seconds. Are you ready?

D. INSTRUCTIONS TO SUBJECTS IN DELAY 3 AND NOISE GROUP

These instructions were the same as those in section C followed by those in section B.

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